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EP 1145896 A
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FR 002777232 A

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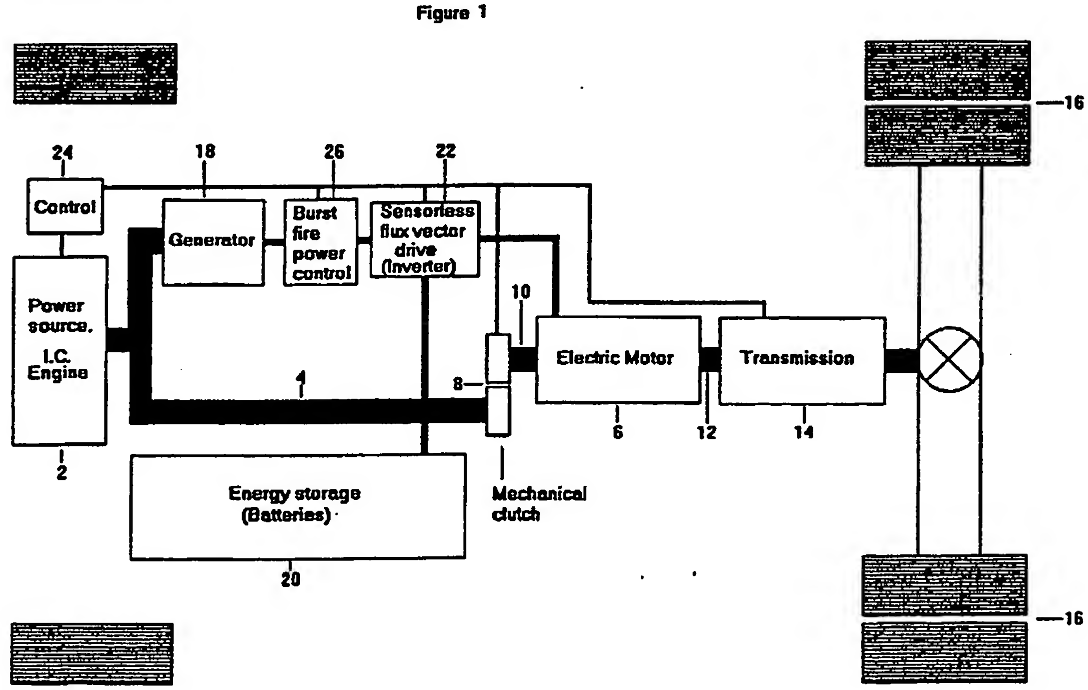
(54) Abstract Title

A series or parallel hybrid drive

(57) A split hybrid drive for driving a load such as a vehicle comprises an internal combustion engine (2) and clutch means (8) for disengageably connecting the internal combustion engine to a load (16) to be driven. Electric generator means (18) is connected to the internal combustion engine (2) for charging battery means (20), and means (22) is provided for employing the battery means for driving an electric motor (6), the electric motor being connected to the load (16) to be driven.

Figure 1



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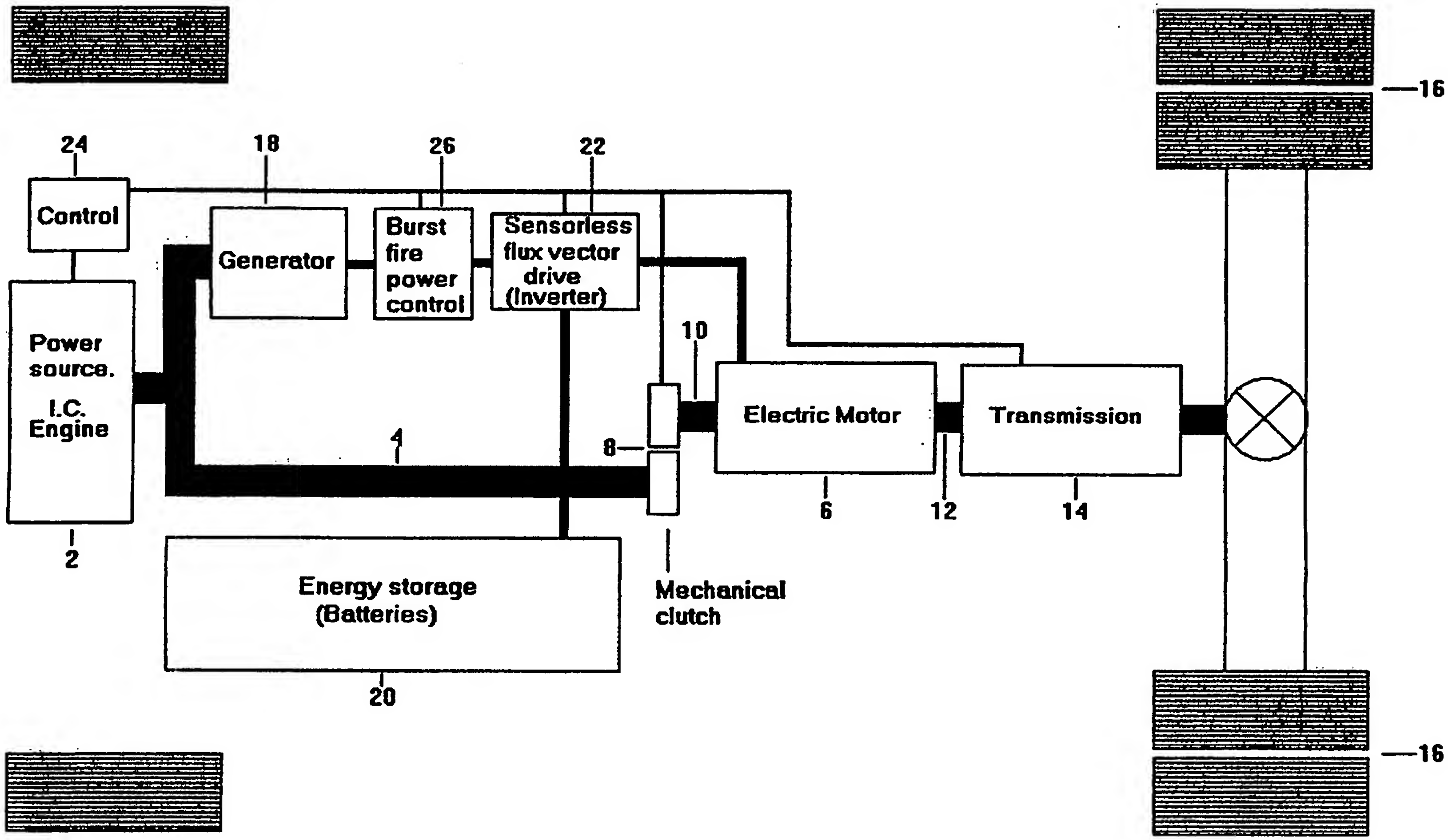
The claims were filed later than the filing date but within the period prescribed by Rule 25(1) of the Patents Rules 1995.

Figure 1/1



24
Control
18
Generator
26
Burst fire power control
22
Sensorless flux vector drive (Inverter)
Power source. I.C. Engine
2
4
8
10
Electric Motor
6
12
Transmission
14
Mechanical clutch
Energy storage (Batteries)
20
16
16

SPLIT HYBRID DRIVE

This invention relates to a split hybrid drive for driving a load such as a vehicle.

A major disadvantage of electrically powered vehicles is their range, which is typically 50 to 80 miles, between charges. In addition, the batteries can take up to 8 hours to charge each time. To overcome these disadvantages a hybrid vehicle may be used.

A hybrid drive for a vehicle is one which incorporates two separate power sources, the most common combination being an internal combustion engine, such as a petrol or diesel engine, in combination with an electric motor. The two power sources can operate independently or together depending on the circumstances.

Known hybrid drives for vehicles are either of the series type or the parallel type.

A series hybrid drive incorporates an internal combustion engine which is not drivingly connected to the wheels of a vehicle, but drives an alternator or other electrical generator which, in turn, charges an electrical storage system such as a battery pack. Because the internal combustion engine is only required to run at a constant speed, it can be arranged to operate with minimum emissions

and optimum efficiency. One of the disadvantages of a series hybrid drive lies in its relatively low efficiency of electrical transmission, but this is compensated by the relatively high efficiency of the internal combustion engine.

A series hybrid drive is generally less powerful that a parallel hybrid drive, but tends to be more efficient. A series hybrid drive is generally best suited to daily commuting trips of less than 25 miles or so, with an occasional longer journey (urban cycle).

A parallel hybrid drive allows the internal combustion engine and the electrical motor to work simultaneously. The internal combustion engine operates continuously and can be supplemented by the electrical motor in a city centre or when additional power is required. On leaving the confines of the city, power can generally be provided by the internal combustion engine alone.

In contrast to an electrically powered vehicle, a parallel hybrid drive offers acceptable performance on relatively fast roads and at the same time affords an opportunity to recharge the battery pack. With a parallel hybrid drive, a relatively small internal combustion engine and electrical motor can be used because the two power sources can operate together. However, the location of the internal combustion engine in the drive train restricts

design freedom. More importantly, if the electrical drive is in use the battery pack cannot be charged because the electrical motor is also used as a generator.

A parallel hybrid drive is more suited to use on motorways and country roads where bursts of speed are necessary. A parallel hybrid drive is also more suited to climbing hills than is a series hybrid drive.

There is therefore a requirement for a hybrid drive which provides the advantages of both series and parallel hybrid drives without their attendant disadvantages.

It is therefore an object of the present invention to provide a hybrid drive which eliminates or ameliorates the disadvantages of known hybrid drives.

According to the present invention there is provided a split hybrid drive comprising:

an internal combustion engine;

clutch means for disengageably connecting the internal combustion engine to a load to be driven;

electric generator means connected to the internal combustion engine for charging battery means; and

means for employing the battery means for driving an electric motor, the electric motor being connected to the load to be driven.

The internal combustion engine may be connected to an input shaft of the electric motor by way of the clutch means. Alternatively, the internal combustion engine may be connected to an output shaft of the electric motor by way of the clutch means.

The internal combustion engine and the electric motor may be connected to the load to be driven by way of a transmission.

The electric motor may be driven by the battery means by way of an inverter.

Control means may be provided to control operation of the clutch means. The control means may additionally control operation of the internal combustion engine and the electric motor.

A burst fire power control means may be provided to regulate the load of the electric generator means.

Thus, the split hybrid drive of the present invention is both a series hybrid drive and a parallel hybrid drive, but

is additionally capable of switching between series and parallel configurations when it is most efficient to do so.

For a better understanding of the present invention and to show more clearly how it may be carried into effect reference will now be made, by way of example, to the accompanying figure which shows diagrammatically one embodiment of a split hybrid drive according to the present invention.

The split hybrid drive shown in the figure comprises an internal combustion engine 2, such as a turbo-charged diesel engine, having an output shaft 4 which is drivingly connected to an input shaft 10 of an electric motor 6 by way of a clutch arrangement 8. The electric motor may be, for example, a high performance squirrel cage motor of well known type. The input shaft 10 of the electric motor 6 is directly coupled to an output shaft 12 such that the internal combustion engine 2, when connected by the clutch arrangement 8, drives through the electric motor 6.

Both the internal combustion engine 2 and the electric motor 6 drive a transmission 14 which in turn drives a load in the form of road wheels 16 of a vehicle (not shown).

The internal combustion engine 2 additionally drives a generator 18, such as a three-phase generator, which continuously (while the internal combustion engine is

running) charges a battery pack 20. The battery pack 20 may comprise lead-acid cells which may be maintained at from 40 to 90 percent of full charge for good service life: such an arrangement generally avoids the need for more expensive battery cells. An inverter (variable frequency drive or sensorless flux vector drive) 22 takes electrical power from the battery pack 20 to drive the electric motor 6 and thence to drive the transmission 14 and the road wheels 16.

A control unit 24 is connected with the clutch arrangement 8 so as to disengage the clutch at low road speeds and/or when there is a high demand for power to the road wheels. In this case, the vehicle is driven solely by electric power, but the internal combustion engine 2 remains operative and continues to charge the battery pack 20 by way of the generator 18.

As the demand for power reduces, for example when cruising road speed is attained, the control unit 24 controls the speed of the internal combustion engine 2 to match the speed of rotation of the motor input shaft 10 and engages the clutch arrangement 8. The internal combustion engine 2 alone then drives the road wheels 16 with the shaft of the electric motor 6 functionally simply as a layshaft between the internal combustion engine 2 and the transmission 14. Nevertheless, the internal combustion engine 2 continues to drive the generator 18 in order to

charge the battery pack 20 to ensure full battery power is available when required. The load of the generator 18 is regulated by a burst fire power controller 26 which enables the control unit 24 to effectively split the power output of the internal combustion engine.

Simply to be able to maintain cruising speed (with additional power for acceleration and/or climbing hills being provided by the electric motor) requires a smaller internal combustion engine than would be the case if the internal combustion engine had to provide power for acceleration and/or climbing hills. The electric motor can be energised as required to supplement the power of the internal combustion engine.

The control unit 24 continually monitors various parameters associated with the hybrid drive and the associated vehicle and selects or combines various modes of operation in dependence upon demand in order to ensure optimum efficiency is maintained.

The various modes of operation include steady state cruise, urban cycle, full power, short duration full power, deceleration (or continuous braking).

Steady state cruise falls into two sub-modes: steady state cruise at maximum cruising speed, and steady state cruise at speeds other than maximum cruising speed. When cruising

at maximum cruising speed, the internal combustion engine 2 is operated at about 80 percent of rated output with the power being split with about 70 percent of rated output to the transmission 14 and about 10 percent of rated output to the generator 18. Should the battery pack 20 become fully charged at any time, the internal combustion engine can be operated at a lower percentage (e.g. 70 percent) of its rated output and thereby reduce fuel consumption. Similarly, if, during steady state cruise, less than about 70 percent of rated output is required to maintain vehicle speed, the internal combustion engine can be operated at a lower percentage of its rated output. It should be noted that during steady state cruise at maximum cruising speed the internal combustion engine is providing all the motive force to propel the vehicle. If additional power is required to maintain vehicle speed the system switches to full power mode. During steady state cruising the electric motor 6 "freewheels" because no power is supplied to the motor from the inverter 22. In this mode the motor 6 simply provides a mechanical connection between the transmission 14 and the internal combustion engine 2.

When cruising at a speed other than maximum cruising speed the internal combustion engine 2 is connected to the transmission 14 by way of the clutch arrangement 8 in dependence upon the state of battery charge and upon whether gear ratios are available to permit efficient operation. An internal combustion engine generally has an

optimal speed at which it operates most efficiently and the control unit 24 operates to engage the internal combustion engine 2 when the vehicle speed and gear ratios are such that the internal combustion engine can operate in the region of its optimal speed.

Urban cycle is when very frequent load variations are encountered. In this mode the internal combustion engine 2 is disengaged from the transmission 14 by means of the clutch arrangement 8 and all the motive force to propel the vehicle is provided by the electric motor 6. The control unit 24 varies the speed of the internal combustion engine between a standby speed and a higher speed depending on the charging level of the battery pack 20. Standby speed will generally be a level at which the generator 18 produces sufficient power to operate ancillary equipment such as air conditioning, lights, power steering and the like. At higher speeds the burst fire controller 26 is used to operate the generator 18 in order to charge the battery pack 20 to a predetermined upper level, for example about 95 percent of its fully charged capacity. It is unnecessary or undesirable to charge the battery pack 20 to 100 percent of its capacity because of the potential for regenerative power in deceleration mode as will be described in more detail hereinafter.

When the battery pack charge level has reached the predetermined upper level, the speed of the internal

combustion engine is reduced to standby speed until the battery pack charging level falls to a predetermined lower level, for example about 30 to 40 percent of the fully charged capacity, when the speed of the internal combustion engine 2 is again raised to re-charge the battery pack 20.

In full power mode the internal combustion engine 2 is disengaged from the transmission 14 by means of the clutch arrangement 8 with the electric motor 6 providing the entire motive power for the vehicle. Full power mode is similar to urban cycle mode, but in the case of full power mode the control unit 24 monitors the rate at which power is being used from the battery pack 20 and increases the speed of the internal combustion engine 2 and the generator 18 load to maximum before the battery pack 20 reaches its minimum charge level. It should be noted full power is maintained for no longer than a predetermined time depending upon the capacity of the battery pack and the percentage of full power the generator is capable of supplying. As a guide, the more likely the hybrid drive is to be operating at full power, the greater the power of the internal combustion engine/generator combination required. For a 410 hp tractor unit, the internal combustion engine power would generally be about 180 hp.

Short duration full power mode arises when more power is required than is available from the internal combustion engine 2 in order to maintain a steady state cruise. In

this mode the electric motor 6, which functions simply as a layshaft during steady state cruising, is energised by way of the inverter 22 to take power from the battery pack 20 and to supplement the power of the internal combustion engine 2. The electric motor 6 provides additional torque to the transmission to maintain the cruising speed when the internal combustion engine 2 is unable to do so alone, for example, when the vehicle encounters a hill, but it is desired to maintain a constant speed. In addition, the motor 6 provides additional torque to enable the vehicle to overtake a slower vehicle. In this mode, should the vehicle speed drop to a value outside the efficient operating range of the internal combustion engine 2 for any particular gear ratio of the transmission 14, then the clutch arrangement 8 is activated to disengage the internal combustion engine and to revert to full power mode.

Deceleration or continuous braking mode (regenerative power) arises, for example, when the vehicle is slowing or descending a hill. In this mode the clutch arrangement 8 is activated to disengage the internal combustion engine 2 from the transmission. Additionally, the generator load is set to zero and the internal combustion engine is set to operate at idle speed (that is, sufficient only to power ancillary equipment). The electric motor 6 generates electrical power which is used to charge the battery pack 20 by way of the inverter 22.

Because the torque and speed of the electric motor 6 and the torque and speed of the internal combustion engine 2 are controlled directly by the control unit 24, precise limits can readily be established for, for example, maximum speed, maximum torque onset, vehicle acceleration and vehicle onset acceleration (the first derivative of vehicle acceleration). The established limits can provide a high degree of mechanical sympathy and ensure the various components operate in their most efficient ranges, thereby resulting in improved fuel consumption, reduced emissions and consequently lower service costs.

It should be noted the clutch arrangement 8 need not be positioned between the internal combustion engine 2 and the electric motor 6. The clutch arrangement may alternatively be positioned between the electric motor 6 and the transmission 14, or may be incorporated into the transmission 14 itself.

The control unit 24 may comprise a programmable logic controller (PLC), or may alternatively comprise a processor and memory arrangement of a programmable logic array (PLA). The control unit 24 monitors all the required variables for efficient operation of the split hybrid drive and decides in which mode the drive should operate. The variables to be monitored fall into two groups, primary and secondary, depending on the relative importance of the variable concerned.

Primary variables are used to determine the operating mode of the drive and include: battery pack 20 charge state, internal combustion engine 2 load, electric motor 6 load, vehicle speed, power request (accelerator pedal position), braking torque request (brake pedal position) and generator output voltage.

Secondary variables are used in relation to specific operating modes and include: cooling water temperature for the internal combustion engine, oil pressure for the internal combustion engine, temperature of the electric motor, temperature of the inverter, temperature of the battery pack and temperature of the generator.

The control unit 24 directly controls the speed and load of the internal combustion engine 2, the load of the generator 18 (by way of the burst fire controller 26), engagement and disengagement of the clutch arrangement 8, the rates of charging and discharging of the battery pack 20 (by way of the load of the electric motor 6 and the load of the generator 18) and the gear ratio of the transmission 14.

CLAIMS

1. A split hybrid drive comprising:

an internal combustion engine;

clutch means for disengageably connecting the internal combustion engine to a load to be driven;

electric generator means connected to the internal combustion engine for charging battery means; and

means for employing the battery means for driving an electric motor, the electric motor being connected to the load to be driven.

2. A hybrid drive as claimed in claim 1, wherein the internal combustion engine is connected to an input shaft of the electric motor by way of the clutch means.

3. A hybrid drive as claimed in claim 1, wherein the internal combustion engine is connected to an output shaft of the electric motor by way of the clutch means.

4. A hybrid drive as claimed in any preceding claim, wherein the internal combustion engine and the electric motor are connected to the load to be driven by way of a transmission.

5. A hybrid drive as claimed in claim 4 and including means for changing the gear ratio of the transmission.

6. A hybrid drive as claimed in any preceding claim, wherein the electric motor is driven by the battery means by way of an inverter.

7. A hybrid drive as claimed in any preceding claim, wherein control means is provided to control operation of the clutch means.

8. A hybrid drive as claimed in claim 7, wherein the control means additionally controls operation of the internal combustion engine and the electric motor.

9. A hybrid drive as claimed in any preceding claim, wherein a burst fire power control means is provided to regulate the load of the electric generator means.

10. A hybrid drive as claimed in any preceding claim, wherein the generator is adapted to charge the battery means whenever the internal combustion engine is running.

11. A split hybrid drive substantially as hereinbefore described with reference to, and as shown in, the accompanying drawing.

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Application No: GB 0110385.2
Claims searched: 1 - 10
Examiner: Tom Sutherland
Date of search: 22 July 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): B7H (HDE)

Int Cl (Ed.7): B60K

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X, E	EP 1145896 A	(TOYOTA) See, e.g., Figs 16 and 17 and paragraphs 0167 to 0173.	1 to 3, 6 to 8, 10
X, E	EP 1002689 A	(FUJI) See paragraph 0010, the Figs.	1 to 8, 10
X	EP 0648635 A	(DOVERI) Whole document.	1, 4, 6 to 8, 10
X	EP 0136055 A	(LUCAS) See Fig. 1 and page 4.	1, 2, 4, 6, 7, 8, 10
X	FR 2777232 A	(RENAULT) See the Figs, engine 1, alternator 8, clutch 4, motor 9, gearbox 2.	1, 3 to 8, 10.
X	JP 10327504 A	(MITSUBISHI) See abstract and Figs.	1 to 8, 10.

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& Member of the same patent family	E Patent document published on or after, but with priority date earlier than, the filing date of this application.